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Capnography Monitoring Education for the Perianesthesia Nurse

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Doctor of Nursing Practice

Final Project Report

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Abstract

Background: Respiratory compromise is one of the most common complications that occur in the Post Anesthesia Care Unit (PACU) and accounts for half of the closed claims involving death in the PACU. However, with appropriate monitoring like capnography, identification of respiratory depression or apnea can occur prior to the adverse respiratory events (ARE). Although capnography is not currently considered a standard monitor in the PACU, it retains many advantages when used in conjunction with pulse oximetry and other standard monitors. Current research supports its use, and many organizations have created position statements and clinical practice recommendations for the use of capnography when patients are given any pharmacotherapeutic that alters sensorium. A knowledge deficit regarding capnography has been found among the perianesthesia nurses of the Indiana University Health Arnett Hospital, and in-service training was deemed a necessity in improving the quality of care provided to the patients.
Aim: This project aims to evaluate a knowledge deficit about the utilization and interpretation of capnography among the perianesthesia nurses and subsequently provide in-service training.
Methods and Procedure: A repeated measures, pre/post-test design was utilized to evaluate perianesthesia nurses ($n = 23$). A dependent paired samples t-test was used to compare mean score differences between the pre-and post-test scores. A 15 minutes in-service session was provided in the PACU to a group of 2-5 perianesthesia nurses at the time for three days.
Results: Post-test scores were significantly higher than the pre-test scores following the educational intervention ($p \leq 0.001$), based on a two-tailed Wilcoxon ranked test.
Conclusion: Providing education on the use and interpretation of capnography resulted in better post-test scores indicating an increased acquisition of knowledge pertaining to capnography.

Keywords: capnography monitoring, PACU monitoring, respiratory depression in PACU.

Capnography Monitoring Education for the Perianesthesia Nurses

Introduction

Significance

In 2010, there was an estimated 51.4 million inpatient and 53.3 million outpatient surgical procedures performed in the United States (National Quality Forum, 2019). After surgery requiring sedation or anesthesia, patients are transferred to the Post Anesthesia Care Unit (PACU) for intensive evaluation of any potential adverse outcomes that can occur as the result of the surgery or the anesthesia they received. The overall PACU complication rate ranges from 5% to 30% and includes cardiovascular, respiratory complications, and medication errors (Bothner, Georgieff, and Schwilk, 1999). Of the total complications, adverse respiratory events (AREs) account for 43% of the events. These events mostly occur in patients who present with no or minor preexisting conditions (Kluger & Bullock, 2002; Faraj et al., 2012). The patient is at risk for an ARE due respiratory compromise that can occur as the result of residual anesthetic effects, opioid-induced respiratory depression or patient-related factors (Kellner, Urman, Greenberf, & Brovman, 2018).

Furthermore, obesity, obstructive pulmonary disease states, diabetes, advanced age, and male sex are some of the factors that can contribute to respiratory compromise in the PACU (Pederson, Viby-Mogensen, & Ringsted, 1992; Faraj et al., 2012). Compounding the problems are the requirements for opioids, known respiratory depressants, to treat somatic pain resulting for surgical insult. More than 80% of patients undergoing surgical procedures require opioids to manage their pain (Luo & Min, 2017). However, the opioids used in the PACU, especially with

Patient Controlled Analgesia (PCA) infusion, contributed to significant respiratory depression without appropriate monitoring (Luo & Min, 2017; Makoyi, 2018). It was also noted that postoperative AREs extended the length of stay in the hospital by nine days, added more than $53,000 to the hospital costs and increased rate of mortality by 22% (Zhan & Miller, 2003; Fleisher & Linde-Zwirble, 2014).

Nevertheless, the advancement of technology and the introduction of new drugs with safer profiles have improved patient care in the perioperative setting (Kellner, Urman, Greenberf, & Brovman, 2018). Capnography monitoring is one such technology when used in conjunction with other monitors, can provide the nurse with real-time ventilator monitoring of the patient in PACU to ameliorate AREs (Kellner, Urman, Greenberf, & Brovman, 2018). Numerous studies have demonstrated that capnography monitoring detects respiratory depression earlier than pulse oximetry and can potentially prevent catastrophic events (Zhang et al., 2017; Foulapdpour, Jesudoss, Bolden, Shaman & Auckley, 2016). Geralemou, Probst, and Gan (2016) mentioned that capnography could detect the change in patients' ventilation anywhere between 12 and 271 seconds before pulse oximetry or respiratory rate.

According to Haret, Kneeland, and Ho (2012), the purpose of the PACU is to "allow centralization of care by a group of specially trained nurses who are expert in interpreting and responding to the events of the brief but intense period immediately following a procedure requiring anesthesia" (p. 57). Knowing that AREs are the primary cause of morbidity in the PACU as well as the costs associated with negative outcomes, it is paramount for perianesthesia nurses to be educated on capnography monitor use and interpretation, which will help promote timely interventions that will hopefully prevent respiratory compromise leading to an ARE.

Background

As part of the curriculum for the Nurse Anesthesia program, Marian University Student Registered Nurse Anesthetists (SRNAs) are required to rotate to different clinical sites around the state of Indiana to acquire knowledge, skills, and competencies in the field. During the clinical rotation at Indiana University Health Arnett Hospital (IU Health Arnett) at Lafayette, Indiana, this SRNA encountered a potential issue as a large number of perianethesia nurses lacked the necessary knowledge regarding capnography monitoring. This issue was identified during informal observations and ultimately confirmed through dialogue with the peri-operative services educator and anesthesia personnel (L. Sherman, personal communication, September 13, 2018). Due to the amalgamation of the exchanges between the SRNA and the staff and the informal observations, the information demonstrated an apparent deficit in knowledge regarding capnography monitoring among the perianesthesia nurses. The knowledge deficit was the reason for the need to develop and implement this Doctor of Nursing Practice (DNP) project.

During different dialogues with the peri-operative services educator, it was revealed a lack of an educational plan regarding capnography monitoring for the PACU might contribute to the knowledge deficit; and the monitors in this unit could not detect the end-tidal CO_2 via capnography (L. Sherman, personal communication, September 20, 2018). At the same time, the unit possessed only one portable capnography monitor, and most of the perianesthesia nurses are not aware of its utility.

The American Society of PeriAnesthesia Nurses (ASPAN) provides standards and practice guidelines for the PACU, and the perianesthesia nurses should be familiar with these recommendations in order to provide the highest quality of care possible. ASPAN recognized that capnography monitoring improves quality of care and prevents untoward outcomes

(ASPAN, 2017). With the effort to improve patient outcomes related to AREs, the value of capnography monitoring has been recognized by other healthcare organizations that have a vested interest in the PACU. The Anesthesia Patient Safety Foundation (APSF) encouraged the healthcare workers to use continuous oxygenation (pulse oximetry) and ventilation monitoring (capnography) when patients received a postoperative PCA infusion or a neuraxial opioid (Stoelting & Weinger, 2009).

The American Society of Anesthesiologists (ASA) emphasized the importance of using capnography monitoring outside of the operating room (Kodali, 2013). They also suggested that particular attention towards monitoring ventilation and perfusion during emergencies in the postoperative period. (Apfelbaum et al., 2013). Pulse oximetry, considered a standard monitor in the PACU, measures the amount of oxygen transported by hemoglobin (oxygenation); however, it has limited ability to identify respiratory depression when patients utilize supplemental oxygen (Hutchison and Rodriguez, 2008). On the other hand, capnography provides real-time ventilator data by measuring expired end-tidal carbon dioxide ($EtCO_2$) which can further be used to evaluate ventilation patterns, perfusion, and specific lung disease (Hutchison and Rodriguez, 2008; Makoyi, 2018). As a result, the peri-operative services educator recognized the importance of educating perianesthesia nurses regarding capnography since the unit had plans to purchase and institute a capnography monitoring in the PACU (L. Sherman, personal communication, January 18, 2019). Currently, both the Ambulatory Surgery Center (ASC) and the main hospital have capnographic monitoring capabilities, and the educational project will complement the planned deployment.

Problem Statement

The primary aim of this DNP project was to address the possible knowledge deficit regarding capnography monitoring among perianesthesia nurses in a single level 2 Midwest hospital affiliated surgical center. The objective was to provide in-service training regarding capnography to the perianesthesia nurses. The in-service intervention was intended to increase knowledge regarding capnography use. The ultimate goal of this project is to provide perianesthesia nurses with the knowledge needed to interpret capnography in order to decrease morbidity with AREs. The following problem statement was used to guide this project:

> Among the perianesthesia nurses (P), does an in-service education on capnography monitoring (I) compared to the lack of in-service education (C) result in increased knowledge in the PACU (O)?

Organizational Practice Gap Analysis

A gap analysis tool adapted from the U.S Department of Health & Human Services, Agency for Healthcare Research and Quality, was used to provide a better understanding of the current practice compared to the best practice (Table 1).

Table 1. Gap Analysis Tool

Best Practice	Best Practice Strategies	How Your Practices Differ from Best Practices	Barriers to Best Practice implementation	Will Implement Best Practice (Yes/No; why not)
The use of capnography in the PACU	• Provide education regarding capnography to the perianesthesia nurses • implementation in capnography to the PACU	• Nurses do not usually use capnography monitoring.	Knowledge deficit	Yes.

The current practice guidelines at IU Health Arnett do not require the use of capnography monitoring in the PACU, and there is not a nursing protocol that emphasizes the use of capnography. In the past, IU Health Arnett PACU monitors did not capture the end-tidal CO_2, and the unit used to possess only one portable capnography monitoring for both the main hospital and the Ambulatory and Surgery Center. As previously mentioned, research has demonstrated that the implementation of continuous capnography monitoring in the PACU permits early detection of respiratory depression and improves patient safety and decreases healthcare costs (Geralemou, Probst & Gan, 2016). Although the hospital has updated its PACU monitors, which can measure capnography, the majority of the nursing staff has some knowledge deficit regarding capnography monitoring. Therefore, an in-service training regarding the value and the basic understanding of capnography in the PACU was paramount.

Review of the Literature

Literature Methods

A search of the literature was performed using Medline, Cochrane Collaboration, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and Google Scholar databases. Medical Subject Headings (MeSH) incorporating Boolean phrasing was used in the search and included: "capnography," "CO2 monitoring," "end-tidal carbon dioxide monitoring," "post-anesthesia care unit (PACU)," "recovery room," "postoperative," "obstructive sleep apnea," "sleep apnea," " pulse oximetry", "hypoventilation syndrome," and "obesity" (Makoyi, 2018). There was not a limitation on the year search since capnography monitoring has not been routinely utilized in the PACU setting. Therefore, increasing the search length was expected to increase the available evidence. Only the articles related to the PACU and all age groups and sexes were part of the literature review. Four articles met the requirement for utilization in this DNP project because these articles provide information regarding the value of the capnography monitoring among children, adolescents, and adult patients (Table 2). The frequency of hypoventilation, apnea, oxygen desaturation, postoperative respiratory depression, bradypnea, and nursing observation and intervention were the outcomes of interest. The knowledge gained from these articles triggers the accomplishment of this project.

Literature Synthesis and Discussion

A randomized controlled trial and cross-sectional study discussed the importance of capnography in identifying hypoventilation and apneic events among children in the PACU. In the cross-sectional study, it was reported that the occurrence of hypoventilation and apnea was observed in 45.5% (95% CI 38.5%, 52.5%) of children, while oxygen desaturation was identified in 19% (95% CI 13%, 24%) of children (Langhan, Li, & Lichtor, 2016). The same authors mentioned that hypoventilation (OR 2.3, 95% CI 1.02, 5.3) and apneic events (OR 2.7, 95% CI 1.1, 7) were more noticeable in children who received opioid medication postoperatively. Hypoventilation was mostly noticed in children who received supplemental oxygen (OR 3.1, 95% CI 1.1, 12). Therefore, the same authors encouraged the use of capnography among children when the opioid and supplemental oxygen are utilized postoperatively (Langhan et al., 2016).

In the randomized controlled trial, the participants were randomly selected in order to evaluate if the PACU nurses would be able to view the capnography monitoring (intervention group) or not (control group) (Langhan et al., 2017). The alarm settings were disabled in the control group while the intervention group alarm settings were arranged to alert the staff in case of hyperventilation, hypoventilation, or apnea events. It was reported that capnography monitoring increased the intervention of the nursing staff, which eventually led to decreased adverse events (hypopnea and apnea) among children in the PACU (Langhan et al., 2017). The incidence of hypopneic hypoventilation [5% (95%CI: 2-8%) per minute vs 1 % (95% CI:-1% to 3%) per minute; $P = 0.04$] and apneic episodes [11% (95% CI:8-14%) per minute vs 1.5% (95% CI:-2% to 5%; $P = < 0.001$] decreased dramatically in the intervention group as opposed to the control group (Langhan et al., 2017). However, the rates of oxygen desaturation between both groups seemed not to be different (Langhan et al., 2017).

Among the adult patients, there was one meta-analysis and one prospective observational study that evaluated the importance of capnography monitoring in the PACU. The meta-analysis consisted of nine studies, where five of them examined capnography monitoring. A pooled data from three capnography studies concluded that continuous capnography monitoring detected 8.6% more postoperative respiratory episodes than continuous pulse oximetry (P< .00001). The probability of detecting postoperative respiratory episodes with the use of capnography monitoring was 5.8 times higher than the pulse oximetry monitoring (OR:5.83, 95% CI, 3.54-9.63, $P < .00001$) (Lam et al., 2017). A conclusion was drawn in the meta-analysis study that continuous capnography, together with continuous pulse oximetry yielded information about ventilation. Continuous capnography monitoring identified respiratory events sooner than oxygen desaturation when supplemental oxygen was used (Lam et al., 2017). The same authors emphasized the importance of nursing staff education related to capnography monitoring and the recognition of postoperative respiratory events (Lam et al., 2017).

Although the prospective observational study showed that apneic alert events did not correlate with the hourly nursing observations and the respiratory rate after a cesarean section, the authors suggested further investigation of the value of capnography among high-risk obstetric patients who received opioid (Weiniger et al., 2018).

In all studies reviewed, capnography monitoring detected postoperative adverse events sooner than the pulse oximetry. Also, the incidences of respiratory events were less frequent, and the intervention of nursing staff increased when capnography monitoring was used. Capnography monitoring facilitates the job of perianesthesia nurses during the titration of opioid in the PACU because capnography monitoring can detect opioid-induced respiratory depression (Lam et al., 2017). Therefore, the necessity of education regarding capnography in the PACU appears to be necessary. In sum, the review provides evidence that capnography monitoring is vital in PACU, and nursing staff education is also essential to promote immediate nursing intervention and improve patient outcomes.

Gap and Constraint of the Literature

The primary constraint of the literature was the limited number of selected studies and different level of evidence. Numerous studies with the highest level of evidence had confirmed the value of capnography monitoring in the various healthcare settings except for PACU, which limited the applicability of capnography in the PACU (Makoyi, 2018). The necessity to have more studies with the highest level of evidence was noted in the review. Although the selected articles contained different levels of evidence, half of those articles were at the highest end of the spectrum. Therefore, those articles responded to the purpose of this project as they confirmed the importance of capnography in the PACU. The literature review is summarized in Table 2.

Table 2. Literature Review Matrix

Author/ Year	**Methodology /Sample**	**Purpose**	**Results**	**Conclusions**	**Evidence Rating**
Langham et al, 2016	Observational n = 194	To determine the frequency of hypoventilation and apnea by capnography among children in the PACU.	• Capnography detected hypoventilation or apnea in 45.5% of patients (95% CI 38.5%, 52.5%) • O2 desaturation occurred in 19% of patients (95% CI 13 %, 24%)	Routine monitoring with capnography may improve recognition of respiratory depression and enhance patient safety in the PACU. Education of PACU staff is recommended.	3

Author/ Year	**Methodology /Sample**	**Purpose**	**Results**	**Conclusions**	**Evidence Rating**
Lam et al, 2017	Meta-analysis 1 RCT & 4 observational	Review the effectiveness of continuous capnography monitoring with or without pulse oximetry for detecting postoperative respiratory depression (PORD) and preventing postoperative adverse events.	• Capnography group identify more PORD events than pulse oximetry group $P < .00001$ • Odds of recognizing PORD = higher in the capnography versus pulse oximetry group. OR: 5.83, 95% CI, 3.54 -9.63; $P < .00001$	Capnography provides early warning of PORD before oxygen desaturation. However, improved education and further research with high-quality studies are recommended.	1
Langham et al, 2017	RCT n =201	To identify if children monitored with capnography would have more frequent staff interventions and fewer adverse events than children monitored with pulse oximetry alone.	• Change in rate of hypopneic hypoventilation was faster in the intervention group ($p = .04$) • Change in rate of apnea was significantly different from the control group ($p < .001$) • Bradypnea rates decreased faster in the control group ($p=.05$) • No differences in rates of hypoxemia between groups over time.	Children had fewer episodes of hypoventilation or apnea due to more effective interventions by nursing staff.	2
Weiniger et al, 2018	Prospective observational n = 80	Estimate the number of apneas events	• 198 apnea alert events were detected	Apneic events were not confirmed by	4

Author/ Year	Methodology /Sample	Purpose	Results	Conclusions	Evidence Rating
		while using continuous capnography after cesarean delivery with intrathecal morphine.	• Nurse observation of RR = OR > 14 R =0.05 between capnography and nurse observation.	the intermittent hourly nursing observations. Future studies are needed to examine the role of capnography in at- risk subjects and during at risk periods when receiving sedatives or systematic narcotics.	

Legend:
O2= Oxygen, O2 Sat= Oxygen saturation, PACU= Post-Anesthesia Care Unit, PORD= post-operative respiratory depression, RR= respiratory Rate

Evidence-Based Practice: Verification of Chosen Option

Due to the increased complexity in healthcare and with the effort to improve the quality of care and safety of patients, many healthcare organizations strive to foster quality improvement projects. Based on the review of the literature, an educational intervention was developed as a quality improvement measure. Perianesthesia nurses can be the frontline staff in detecting adverse events that occur in the PACU; therefore, education is a fundamental component in this setting.

Theoretical Framework

A logic model or Logical Framework Approach (LFA) (Figure 1) focuses on a chain of causation or "if-then" connections that lead to intended outcomes (Hayes, Parchman, & Howard, 2011). This framework links the desired results with the different actions taken and the underlying assumptions of the project (Hayes, Parchman & Howard, 2011). The LFA maximizes the possible effort of the project team in their planning, implementing, and evaluating with the goals to reach the desired outcomes (Goeschel, Weiss, & Pronovost, 2012).

The LFA has been successfully used in healthcare for various quality improvement projects. The LFA was used in the planning, implementation, and evaluation of a Comprehensive Unit-Based Safety Program (CUSP) and Central Line-Associated Bloodstream Infections (CLABSI) program in some intensive care units (ICU) (Goeschel, Weiss, & Pronovost, 2012). The framework was also successfully used in a primary care practice-based research network. In this setting, the process for the development of this framework consists of identifying the target audience, identifying and describing assumptions, inputs, and activities, and finally identifying outputs, outcomes and outcome indicators (Hayes, Parchman, & Howard, 2011).

The LFA contains four main components, such as inputs, activities, outputs, and outcomes (Centers for Disease Control and Prevention [CDC], 2014). The inputs, activities, and outputs are considered the “process components” or planning elements of the model; while the outcomes component of the model consists of the intended effects (CDC, 2014). The LFA also identified three different outcomes, such as short-term, intermediate, and long-term outcomes (CDC, 2014). The CDC also developed and used the LFA to evaluate the program for heart disease and stroke prevention activities (2017).

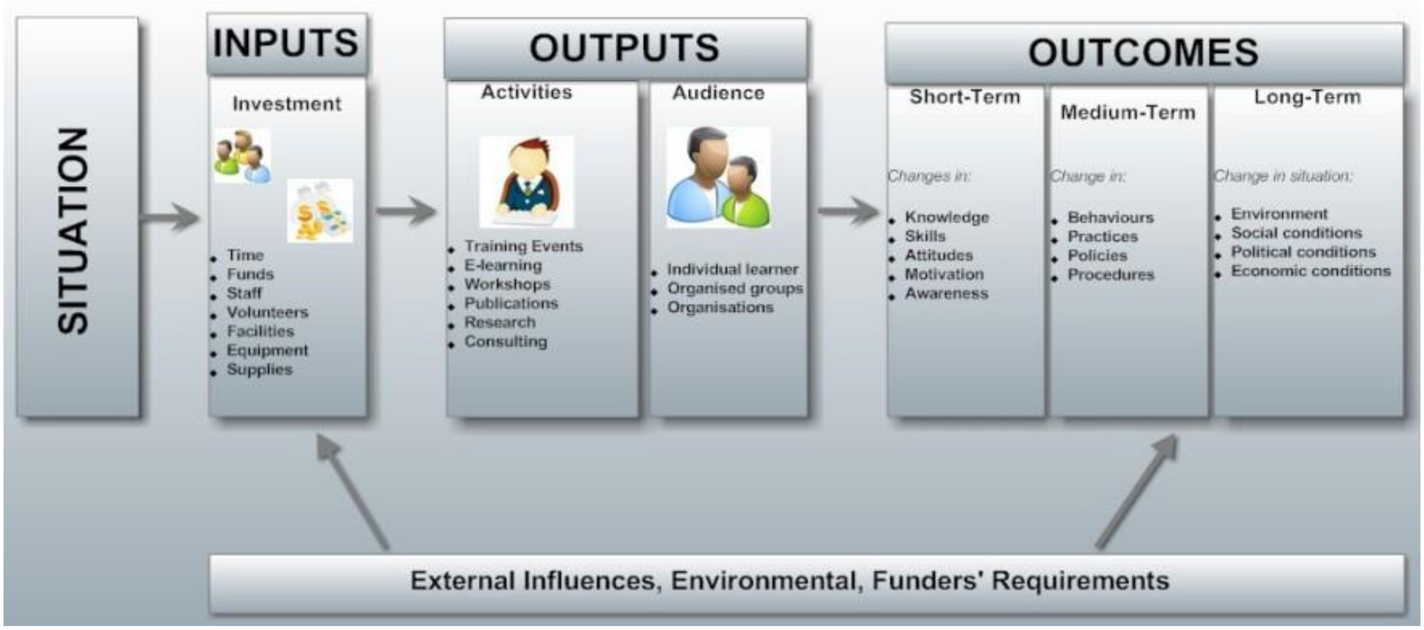

Figure 1. Simple Logic Model adapted from http://click4it.org/index.php/Logic_Model

Goals/ objectives/ expected outcomes

From these underlying assumptions and actions of the LFA framework, the purpose of this DNP project aligns with the LFA as it recognizes the knowledge deficit regarding capnography monitoring among the perianesthesia nurses at IU Health Arnett Hospital. This knowledge deficit required an in-service or training session with the short-term goal of improving the knowledge of the perianesthesia nurses regarding capnography monitoring. The long-term goal will consist of changing behavior, practices, and policies (Figure 2).

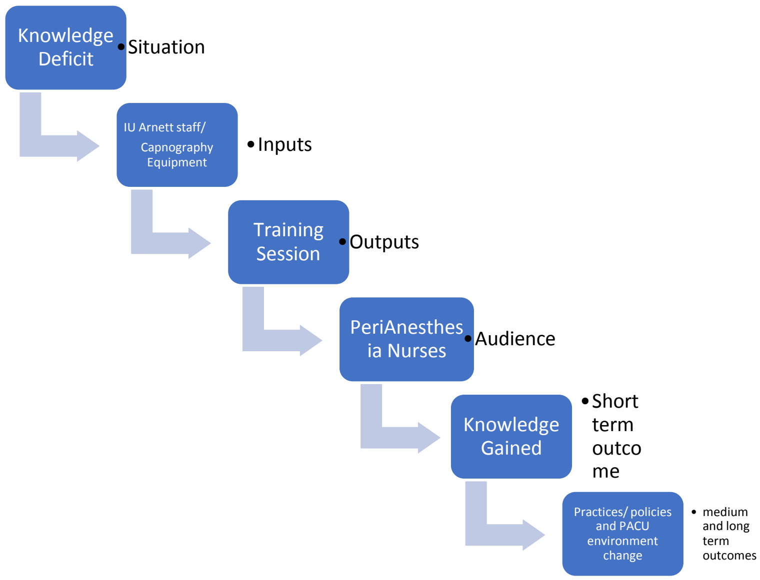

Figure 2. Adaptation of the LFA to the Project Steps

DNP Project Design

Project Site and Population

The educational intervention was performed at Indiana University Health Arnett Hospital (IU Health Arnett). IU Health Arnett is a 191-bed hospital that serves the population of Lafayette, Indiana. This urban acute tertiary center provides diverse general medical and surgical services such as cancer, neurology, orthopedics, heart and vascular, neurosurgery, primary care, sports medicine, geriatrics, pulmonary and lung surgery, gastroenterology and gastrointestinal (GI) surgery, urology, and women's health (Indiana University Health [IU health], 2019**)**. The hospital accounts for 40 specialties and 23 outpatient clinics (IU Health, 2019). Due to its bed capacity and affiliation with IU, IU Health Arnett is considered an urban academic hospital. The main hospital has eight PACU beds, not including the Phase II beds, which are also used as pre-operative rooms for admissions and GI recoveries. The Ambulatory Surgery Center (ASC) has a total of 15 beds for both the Phases I and II of PACU and is located in a separate building, which could be an issue to access the equipment. Currently, IU Arnett hospital has changed all the monitors, all with the capacity to monitor capnography. Therefore, the educational project will complement the planned deployment of the new monitoring as the perianesthesia nurses will have access to the monitoring at the bedside and will be required to use the monitor after this educational intervention.

Setting Facilitators and Barriers

The surgical department has a total of 30 perianesthesia nurses who are cross-trained to work in the PACU for both Phases I and II. Web-based and on-the-job training are the main types of education provided at PACU. However, perianesthesia nurses do not receive formal training in capnography waveform use and interpretation. They are required to have Basic Life Support (BLS) and Advanced Cardiac Life Support (ACLS) training and preference of one year of nursing experience to be hired in the PACU (L. Sherman, personal communication, January 18, 2019).

The perioperative nurse educator was involved in the development of this project by approving this project and acting as a liaison between the SRNA and perianesthesia nurses. IU Arnett hospital in general, and particularly the surgery department staff (perianesthesia nurses and the anesthesia department), and any patients who undergo any surgical procedure are stakeholders who have vested interest in this project.

Methods of Evaluation

Measurement Instruments and Data Collection Procedures

This DNP project consisted of providing education about capnography monitoring to the perianesthesia nurses. The in-service training was provided on April 22nd, April 23rd, and April 29th, 2019 from 8 a.m. – 12 p.m. to capture most of the perianesthesia nurses who may benefit from the education (Appendix A).

The educational intervention was presented in a small group of two to five nurses at the time with each session lasting 15 minutes. First, a participant informed consent (Appendix B) that discusses the terms of the study was distributed. After the informed consent was obtained, the participants were assigned a random numeric identifying code that was used for all other documents associated with the study. Second, a pre-test questionnaire of ten items (Appendix C) along with the demographic survey of five items (Appendix D) were distributed. Next, paper copies of the presentation in the form of PowerPoint (Appendix E) were provided at the beginning of the education to reinforce teaching. Interactions during the teaching were also encouraged. Before the post-test, there was a brief time for questions and answers. Finally, a post-test with ten items was distributed (Figure 3).

The demographic survey, which consists of five items, was solely created for this project to address the experience level of each perianesthesia nurse (nursing, Intensive care unit and PACU experience), others nursing certification and any previous capnography education. The survey was also useful to evaluate if there is any relationship between the demographic survey results and the pre-test and post-test results.

The pre-test and post-test consist of identical items that were adapted to determine if there is an improvement in knowledge regarding capnography after the in-service training. The test contains information that was discussed during the PowerPoint presentation. All items were multiple-choice questions. The learning objectives were composed based on level 1 to 3 of the Bloom’s taxonomy model of educational learning. Each learning objective matched with the material provided in the PowerPoint presentation. The pre-test and post-test were adapted from Covidien and Northwest Community EMS system. Covidien is a global medical products manufacturer that was purchased by Medtronic. Medtronic is one of the healthcare products company that manufactures and supplies capnography monitoring; it also provides clinical education and training regarding their innovation. The Northwest Community EMS system is emergency medical service that provides services to the communities and continuing education materials. The PowerPoint was adapted from the content found in the textbook endorsed by Marian University's Nurse Anesthesia Program, titled Miller's Anesthesia 8th edition by Miller, Cohen, Eriksson, Fleisher, Wiener-Kronish, and Young (Miller et al., 2015). The PowerPoint presentation was also adapted from the Association of Radiology and Imaging Nursing Journal, the Alameda County Public Health Department website, the WebMD website, the PubMed website, Community Health Hospital and McHenry Western Lake County EMS presentation.

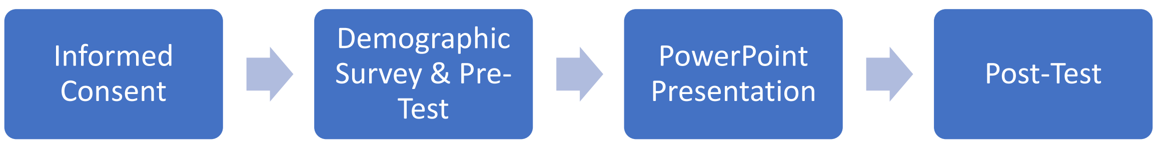

Figure 3. Implementation Procedure

Ethics Considerations/ Protection of Human Subjects

The Institutional Review Board (IRB) of Marian University reviewed the project proposal and judged it exempt from the need for human subjects' protection (Appendix F). Also, the Leighton School of Nursing at Marian University and Indiana University Health Arnett Hospital (IU Health Arnett) have approved the project before its development and implementation. Written informed consent to participate in this project freely was obtained before the intervention. The perianesthesia nurses were able to opt-out of the research but still received the in-service training without any penalty or reprimand. A random numeric code was assigned to each participant to maintain their confidentiality and privacy.

Data Analysis

The educational intervention was evaluated by the pre and post-tests, and statistical analysis was performed using a dependent samples t-test. The dependent samples t-test is known as the paired t-test, or paired samples t-test, which provides a comparison of the mean of two related groups to establish the statistically significant differences that can exist between the mean of these groups (Laerd, 2019). With a dependent t-test, the participants' responses were examined on two different occasions and were part of a single group, i.e., paired (Laerd, 2019).

The information collected before and after the education met the requirement for the dependent samples t-test and was considered as an appropriate method of evaluation for this project. The DNP project examined the knowledge gained regarding the capnography monitoring (dependent variable) by providing a pre-test and post-test to the same perianesthesia nurses on two separate occasions.

The descriptive statistics were also used to describe the data collected from the demographic survey. These data were useful to establish a relationship between the results of the pre/post-test and the participant's characteristics. It was determined that further statistical analysis of this data would not alter the finding of this project.

Results

Participants Characteristics

All perianesthesia nurses at IU Arnett hospital had at least one year of nursing experience. Two nurses had between one to three years of nursing experience, three nurses had between three to five years of nursing experience, and eighteen nurses had more than five years of experience **(**Figure 4**)**. Among the perianesthesia nurses, five nurses had less than one year of PACU experience, eight nurses had between one to three years of PACU experience, one nurse had three to five years of PACU experience, and nine nurses had more than five years of PACU experience (Figure 4). Fourteen nurses had zero ICU experience, six nurses had one to three years of ICU experience, one nurse had three to five years of ICU experience, and two nurses had more than five years of ICU experience (Figure 4).

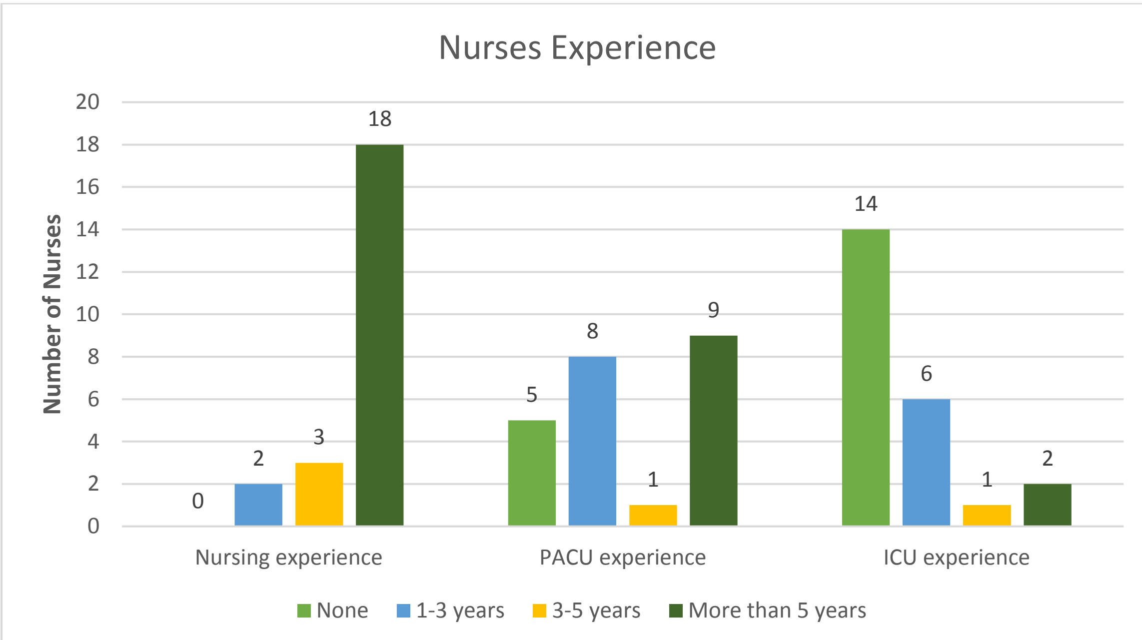

FIGURE 4. Nursing, PACU and ICU Experience

Five perianesthesia nurses possessed an additional nursing certification, while eighteen nurses did not possess any certifications at all (Figure 5). One nurse reported attending a prior capnography education (Figure 6)

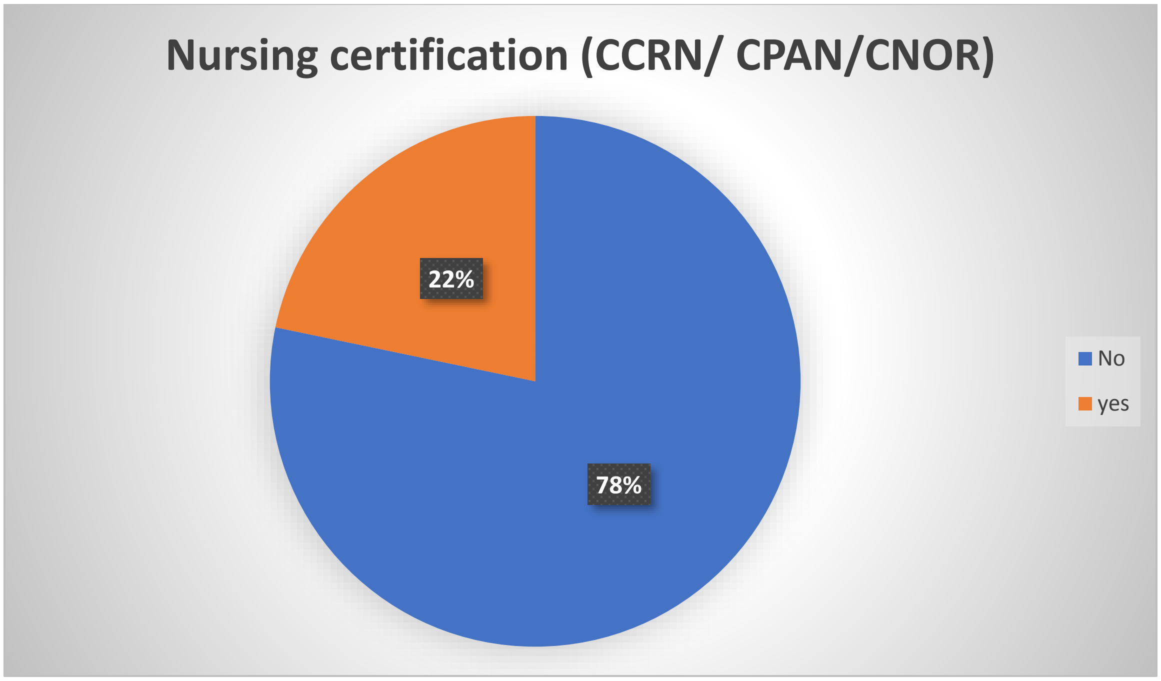

FIGURE 5. Additional Nursing Certification

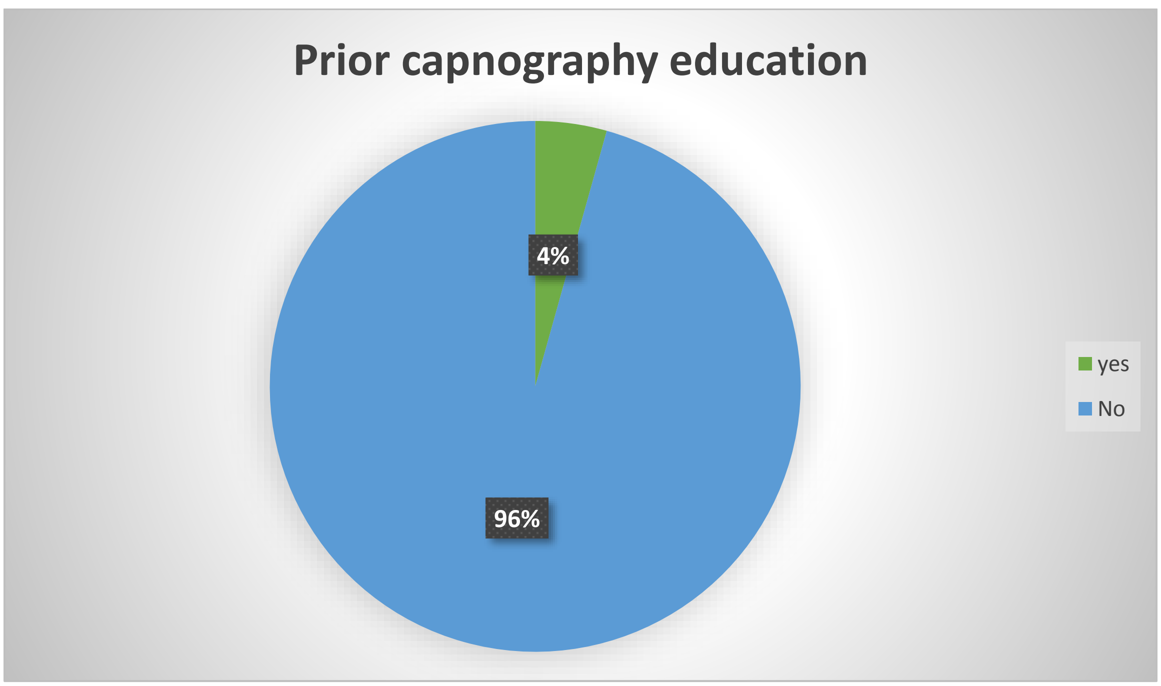

FIGURE 6. Prior Capnography Education

Pre-test and Post-test Results

Pre-test and Post-test Scores. Twenty-nine pre-tests and post-tests were distributed to the perianesthesia nurses at IU Arnett Hospital. Out of the twenty-nine distributed tests, six pre-tests were excluded due to the lack of post-test (Figure 7). However, the mean pre-test of those excluded did not differ from the mean pre-test of those participants who were included.

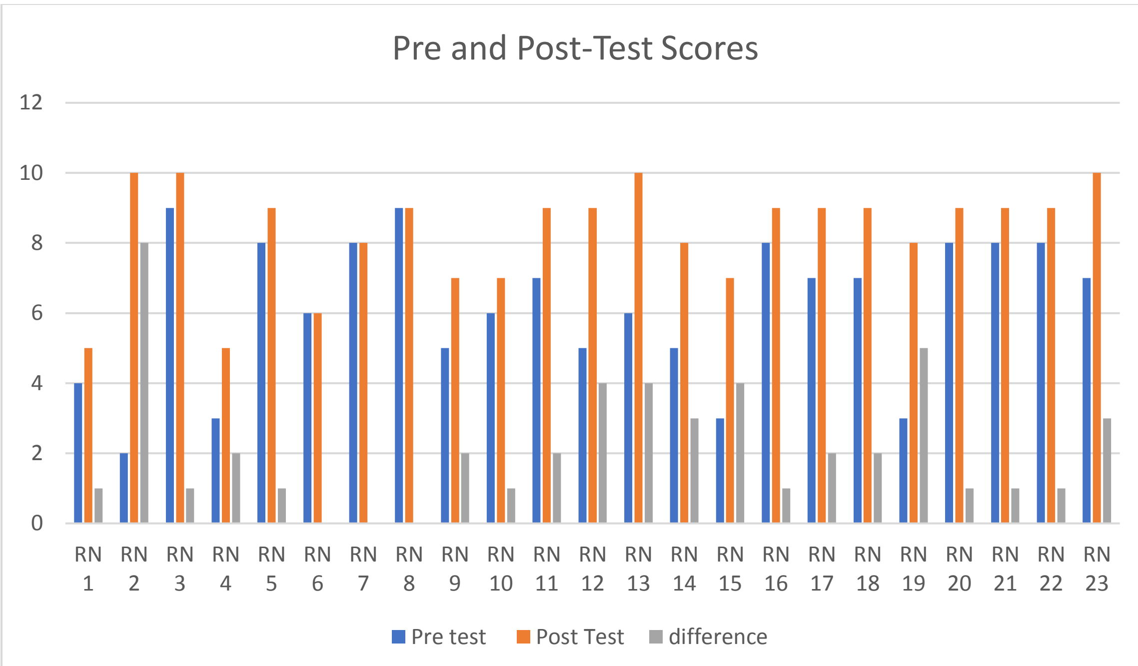

FIGURE 7. Pre-test and Post-test Scores

Combined Participants Demographic Results and Pre/ Post-test Results

The level of nursing, ICU, or PACU experience, as well as any additional nursing certification and prior capnography education, did not have any impact on the pre/ post-test result. After carefully analyzing the results gathered from both the pre-test and post-test, it is safe to assume that regardless of one’s experience, the difference that was yielded were virtually scattered. Just by merely taking a glimpse at the data highlighted on the chart, many nurses who had a higher level of PACU experience seemed to perform worse than those who had little to no experience (Figure 8). At the same time, there were also nurses involved that had minimal experience and still performed poorly on either or both the pre-test and post-test. Due to this, one can conclude that there is virtually no relationship between the level of experience or additional nursing certification one holds and their level of knowledge in regard to capnography monitoring.

RN Participants	YEAR of RN experience	YEAR ICU EXPERIENCE	YEAR PACU EXPERIENCE	NURSING CERTIFICATION	Prior capno education	PRETEST	POST TEST	DIFFERENCE
1	> 5	0	1 – 3	No	No	4	5	1
2	> 5	2	>5	No	No	2	10	8
3	> 5	>5	3 – 5	No	No	9	10	1
4	> 5	0	0	Yes	No	3	5	2
5	3- 5	0	<1	No	No	8	9	1
6	> 5	1 – 3	>5	No	No	6	6	0
7	> 5	0	>5	No	No	8	8	0
8	3 – 5	0	1 – 3	No	No	9	9	0
9	3 – 5	0	0	No	No	5	7	2
10	> 5	3 – 5	>5	No	yes	6	7	1
11	>5	>5	>5	Yes	No	7	9	2
12	>5	0	>5	No	No	5	9	4
13	> 5	0	>5	No	No	6	10	4
14	>5	0	1 – 3	No	No	5	8	3
15	>5	1 – 3	>5	No	No	3	7	4
16	> 5	0	>5	No	No	8	9	1
17	2 – 3	0	1- 3	Yes	No	7	9	2
18	>5	0	1 – 3	No	No	7	9	2
19	2 – 3	0	0	No	No	3	8	5
20	>5	1 – 3	0	Yes	No	8	9	1
21	>5	1 – 3	1 – 3	No	No	8	9	1
22	>5	0	1 – 3	No	No	8	9	1
23	>5	1 – 3	1 – 3	No	No	7	10	3

FIGURE 8. Combined Participants Demographic and Pre/Post-tests Results

Means of Pre-test and Post-test. The mean of pre-test was significantly lower than the mean of the post-test (Figure 9).

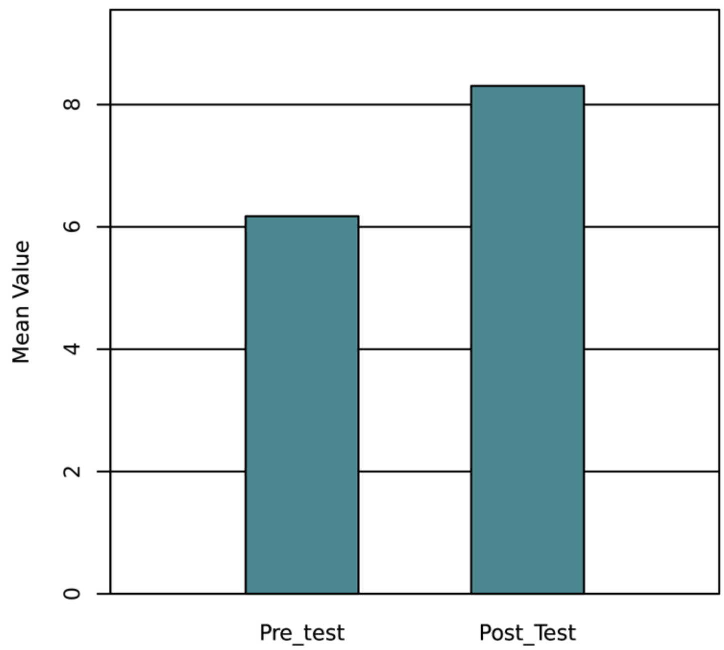

Figure 9. The Means of Pre-test and Post-test.

Power Analysis. The University of British Columbia online program was used to determine the minimally appropriate sample size of the study. Using the power of 0.80 of alpha of 0.05 and assuming a normal distribution, the minimum required sample size per group was eight. However, subsequent results of the Shapiro-Wilk test were significant, indicating a violation of the normality assumption. Therefore, the non-parametric two-tailed Wilcoxon signed rank test was conducted.

The Intellectus Statistical online program was used. The results were statistically significant (alpha = 0.05, v = 0.00, z = -3.96, $p < .001$), demonstrating that the differences in pre-test and post-test scores are significant with the median pre-test scores (Median = 7.00) lower than the median post-test scores (Median = 9). This indicates it is likely the education intervention led to a statistically significant improvement in the subjects' test scores.   Figure 10 provides the box-plot of the ranked score for the Wilcoxon test.

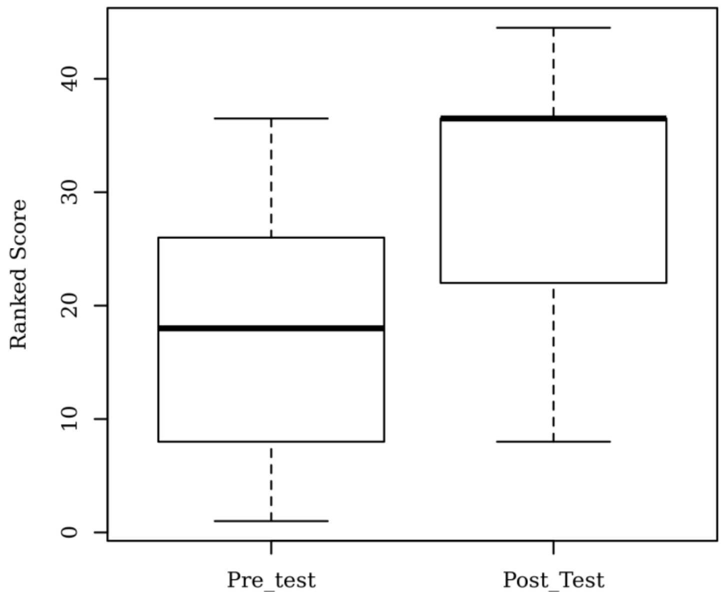

Figure 10. Ranked Values of Pre-test and Post-test

Discussion

Although the participants' demographic survey information did not mirror the results of both the pre and posttest, the in-service training was considered successful, because this educational intervention responded to the self-reported needs of the perianesthesia nurses. An assumption can be made that capnography was a topic that was not adequately highlighted in the PACU orientation. Despite this lack of relationship, the perianesthesia nurses demonstrated an enhancement of knowledge regarding capnography monitoring after the educational intervention. The educational model and subsequent project addressed the project PICO question:

Among the perianesthesia nurses (P), does an in-service education on capnography monitoring (I) compared to the lack of in-service education (C) result in increased knowledge in the PACU (O)?

The intervention yielded a positive response to the educational project and may potentially lead to improved safety and quality of care for patients at IU Arnett Hospital. Continuous capnography education should be a part of the required training in the PACU. This quality improvement project would also be more beneficial if other stakeholders, such as the perianesthesia nurses' managers and perianesthesia nurses could better facilitate training. Implementation of the educational model would likely have been more effective, if the nurses had been able to take a break to solely focus on education rather than being distracted by patient care during the training. The education was provided at the nursing station, where nurses had their attention divided. Therefore, web-based training in which nurses participate during periods when they do not have patient assignments or other clinical loads may be more beneficial. Based on the framework used, the short-term goal of improving the level of knowledge regarding capnography was achieved; however, the long-term goal of changing practices and behaviors requires a multifaceted and longer-term approach. To examine the validity of the data, the non-parametric Wilcoxon signed rank test was also performed. The results of the two-tailed Wilcoxon signed rank test were significant, which indicates that the differences between these test scores were unlikely due to random variation. This may suggest learning occurred.

Limitations

The limited time to present the project was considered a significant drawback due to its potential effect on some of the data gathered. Per request of the peri-operative services educator, the time for the pretest, presentation, and post-test was reduced from 20-30 minutes to approximately 15 minutes due to the inability of the nurses to fully participate in the education.

Furthermore, due to the high nursing turnover rates, nurses were unable to leave their station to solely focus on education. This issue only allowed nurses who were not responsible for patients at that particular juncture to be able to actively participate in the capnography module. Some nurses were able to do the pre-test, but were unable to participate in the PowerPoint presentation or the post-test. Due to these issues, the pre-tests for those inactive nurses were unfortunately not included in the analysis. To mitigate this issue, the SRNA was able to add an extra day for training in order to capture the majority of the perianesthesia nurses as much as possible. Regardless of the efforts of the SRNA to capture all of the PACU nurses, a small portion of nurses that participated in the pre-test and PowerPoint presentations were allowed to return the post-test to the perianesthesia nurse educator. Continuing on, another foreseen limitation in the midst of this capnography, was a lack of institutional structure that supported the in-service. With the education not being provided in the learning environment needed for this type of education, and instead, at one of the nursing stations, there is an alarming amount of potential that this negatively affected a lot of the data that was gathered.

Conclusion

AREs are the most common complication encountered in the PACU, and capnography monitoring can facilitate the detection of respiratory complications. Therefore, it is deemed a necessity for expert perianesthesia nurses to identify this issue appropriately and immediately.

In summary, the goal of this project was to evaluate if an in-service training on capnography monitoring will improve the knowledge of the perianesthesia nurses. The educational intervention and the design of which was guided by a logic model, facilitated the achievement of this project. The short-term goal was accomplished as the perianesthesia nurses demonstrated an increase in knowledge regarding capnography monitoring. Although the short-term goal was attained, it is far too soon to assess long-term retention of the knowledge. Continuing education as part of the basic training for the perianesthesia nurses will be beneficial in the long-term sustainability of this quality improvement project. Therefore, the stakeholders should continue to support this quality improvement project by continuously providing a formal education regarding capnography monitoring. Furthermore, the dissemination of this project at Marian University's Leighton school of nursing can promote sustainable changes as future SRNAs may be interested in continuing to provide the education at the same facility.

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Appendix A:

IU HEALTH ARNETT HOSPITAL Confirmation letter

outlook.office.com

Reply all | Delete Junk | •••

[EXTERNAL] in-service

SA

Sherman, Lindsey A <lsherman2@IUHealth.org>

Mon 4/15, 3:23 PM

Bobette N. Makoyi; Stombaugh, Jessica A <jstombaugh@IUHealth.org>; +1 more

Reply all |

Inbox

You replied on 4/15/2019 11:49 PM.

Just a reminder that our CRNA student Bobette will be presenting about end-tidal CO2 monitoring for the ASC on Monday, 4/22 at 9 am, and for the hospital PACU on Tuesday, 4/23 at 9 am.

Appendix B:

Participants Informed Consent

PARTICIPANTS INFORMED CONSENT

This in-service session has been developed as partial fulfillment of the requirements for the Doctor of Nursing Practice (DNP) degree in Nurse Anesthesia at Marian University (MU). This research project is titled: "Capnography Monitoring for the PeriAnesthesia Nurses." The purpose of this project is to enhance the knowledge of the perianestheisa nurses regarding capnography monitoring, which will eventually improve the patient outcomes.

If you agree to take part in this project, you will be completing a five-item demographic survey and a ten-item pretest, then you will be attending a PowerPoint presentation on capnography monitoring, and you will be provided a ten-item posttest. The completion of all of these steps may last 10-15 minutes. There are no anticipated risks associated with participating in this project.

Your records will be kept confidential, and your name will be kept private. Your decision to take part in this research project is entirely voluntary, and you may refuse to participate, or you may withdraw from this project at any time without penalty or reprimand. You may also opt out of the research project but still receive the in-service training. By agreeing to be part of this project, you have the right to have the results of the information gathered from this research project. Your consent to participate in this project is indicated by your voluntary response to the items provided.

The Institutional Review Board (IRB) of MU has reviewed and approved this project proposal, but if you have any questions regarding your rights as a research subject, feel free to contact MU IRB committee at 317-955-6115.

If you have any questions about the research now or during the study, please contact the member of the research team : Bobette Makoyi, bmakoyi@marian.edu, Dr. Stacie Hitt, sfhitt@marian.edu, or Dr. Allison Luellen , aluellen@marian.edu

Your participation is truly appreciated.

Appendix C:

Pre and Post-Test Questionnaire

Capnography Monitoring in the PACU (Pre/Posttest)

1. Choose the best definition for capnography:
    a. Non-invasive continuous measurement of excreted carbon dioxide in perspiration
    b. Invasive measurement of exhaled oxygen and carbon dioxide in the breath
    c. Non-invasive continuous measurement of carbon dioxide in the breath
    d. Measurement of arterial carbon dioxide
    Answer C
2. Capnography can provide information about which of the three physiological functions?
    a. Metabolism, perfusion, and ventilation
    b. Oxygenation, ventilation, and metabolism
    c. Perfusion, neurological, and ventilation
    d. None of the above
    Answer A
3. What information does a capnography sensor obtain?
    a. CO level
    b. O2/CO2 ratio
    c. Oxygen level
    d. CO2 waveform
    Answer D
4. What is a cause of a low ETCO2 level?
    a. Fever
    b. Hyperventilation
    c. Pain
    d. Hyperoxia
    Answer B
5. What is an elevated ETCO2 a sign of?
    a. Alkalosis
    b. Hypoxia
    c. Respiratory failure
    d. Carbon monoxide poisoning
    Answer C
6. What is a consequence of hyperventilation?
    a. Hypercarbia
    b. Decreased cardiac output
    c. Increased cerebral perfusion
    d. Increased coronary perfusion
    Answer B
7. What ETCO2 reading would you expect in a patient who is hypoventilating from shivering?
    a. Decreased

b. Normal
c. Elevated
Answer C

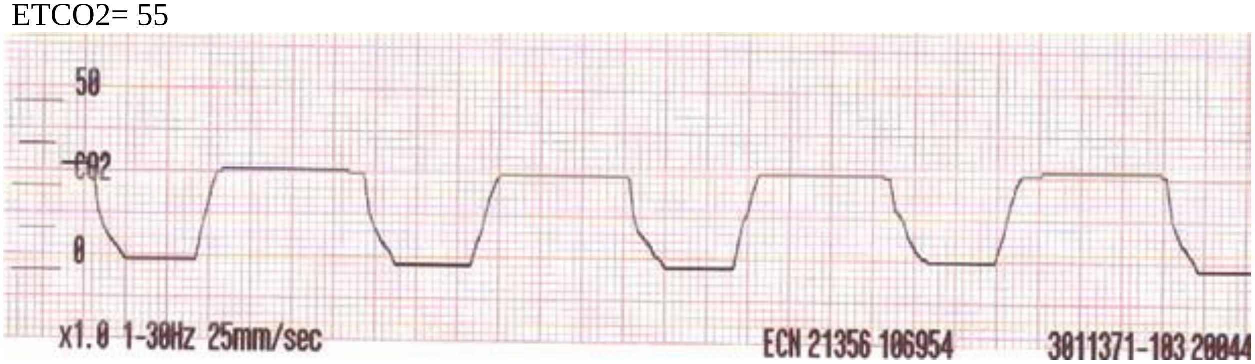
8. Identify this waveform:
ETCO2= 25

a. Hyperventilation
b. Hypoventilation
c. Normal
Answer A

9. Identify this waveform:
ETCO2= 42

a. Hyperventilation
b. Hypoventilation
c. Normal
Answer C

10. Identify this waveform:
ETCO2= 55



a. Hyperventilation
b. Hypoventilation
c. Normal
Answer B

References

http://www.nwcemss.org/assets/1/continuing_education/feb_12_-_capnography_PTSQ.pdf.
http://alanbatt.net/wp-content/uploads/2017/02/10_EMS-PreTest-11-25.pdf.

Appendix D:

Demographic Survey

DEMOGRAPHIC SURVEY

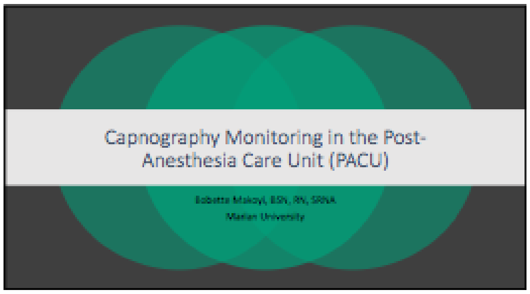
ID number:

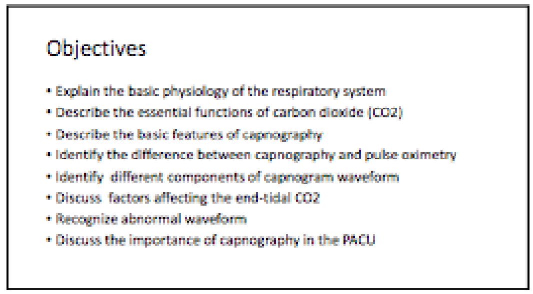
1. How many years of nursing experience do you have?
   a. < 1 year
   b. 2 - 3 year
   c. 3 - 5years
   d. More than 5 years
2. How many years of ICU experience to you have?
   a. None
   b. 1-3 years
   c. 3-5 years
   d. More than 5 years
3. How many years of PACU experience do you have?
   a. None
   b. 1-3 years
   c. 3-5 years
   d. More than 5 years
4. Do you have any nursing certification such as CCRN, CPAN?
   a. Yes
   b. No
   c. Other not listed? Please specify_________
5. Have you ever taken a class regarding capnography monitoring in the past?
   a. Yes
   b. No

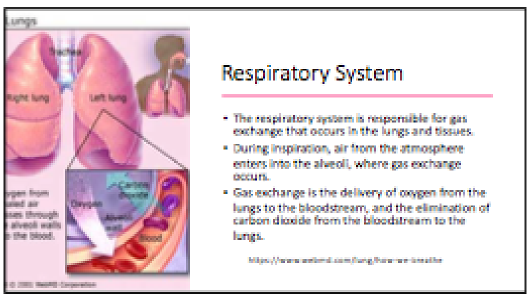
Appendix E:

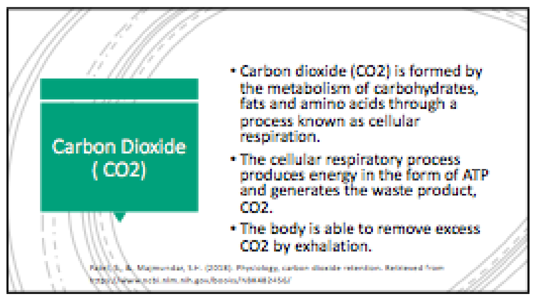
PowerPoint presentation

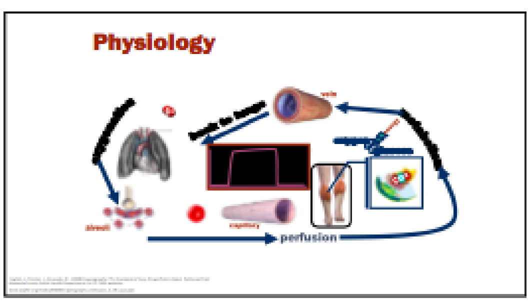
4/17/19

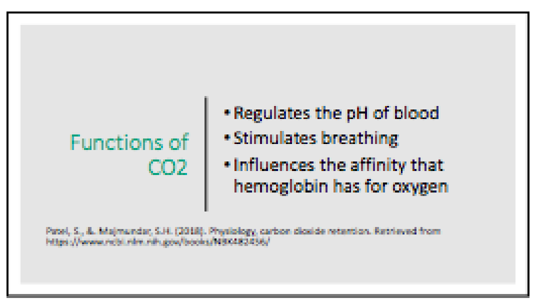

Capnography Monitoring in the Post-Anesthesia Care Unit (PACU)
Marian University


Objectives
• Explain the basic physiology of the respiratory system
• Describe the essential functions of carbon dioxide (CO2)
• Describe the basic features of capnography
• Identify the difference between capnography and pulse oximetry
• Identify different components of capnogram waveform
• Discuss factors affecting the end-tidal CO2
• Recognize abnormal waveform
• Discuss the importance of capnography in the PACU

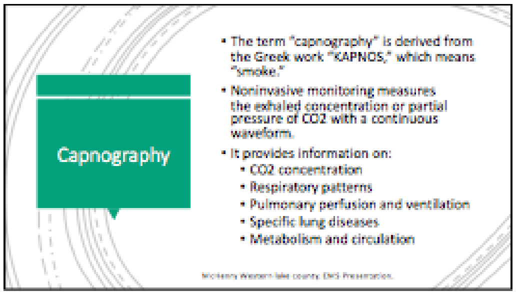

Lungs
Trachea
Right lung
Left lung
Oxygen
Blood
Respiratory System
• The respiratory system is responsible for gas exchange that occurs in the lungs and tissues.
• During inspiration, air from the atmosphere enters into the alveoli, where gas exchange occurs.
• Gas exchange is the delivery of oxygen from the lungs to the bloodstream, and the elimination of carbon dioxide from the bloodstream to the lungs.
https://www.webmd.com/lung/how-we-breathe

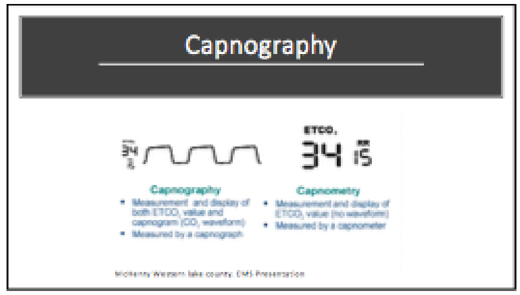

Carbon Dioxide
(CO2)
• Carbon dioxide (CO2) is formed by the metabolism of carbohydrates, fats and amino acids through a process known as cellular respiration.
• The cellular respiratory process produces energy in the form of ATP and generates the waste product, CO2.
• The body is able to remove excess CO2 by exhalation.

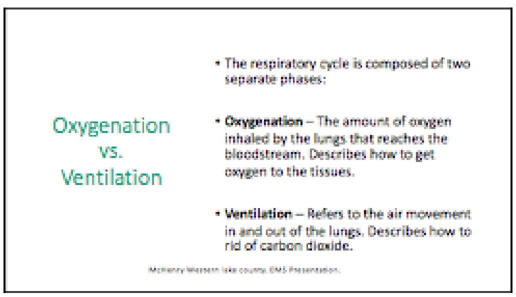

Physiology
perfusion

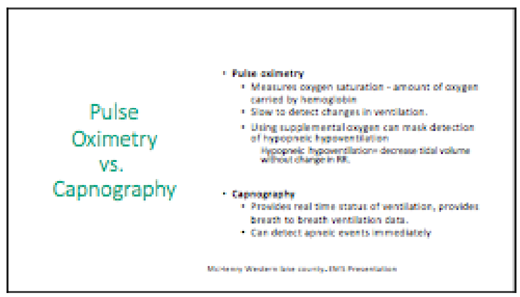

Functions of CO2
• Regulates the pH of blood
• Stimulates breathing
• Influences the affinity that hemoglobin has for oxygen
Patel, S., & Majmundar, S.H. (2018). Physiology, carbon dioxide retention. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK482456/

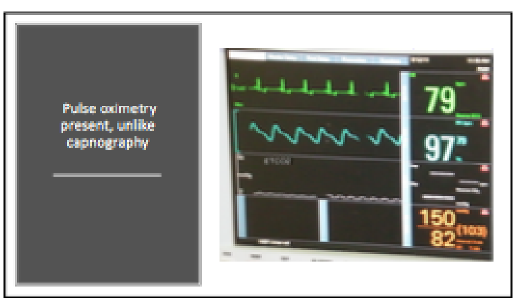
4/17/19

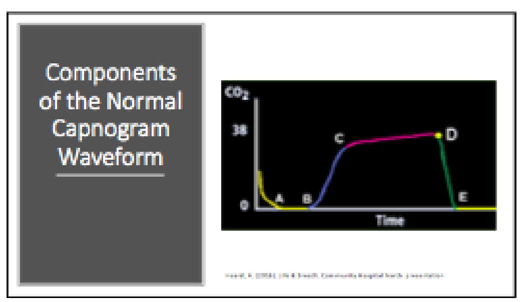

Capnography
The term "capnography" is derived from the Greek work "KAPNOS," which means "smoke."
Noninvasive monitoring measures the exhaled concentration or partial pressure of CO2 with a continuous waveform.
It provides information on:
CO2 concentration
Respiratory patterns
Pulmonary perfusion and ventilation
Specific lung diseases
Metabolism and circulation
Mchenry Western lake county. EMS Presentation.


Capnography
34
Capnography
Capnometry
Mchenry Western lake county. EMS Presentation

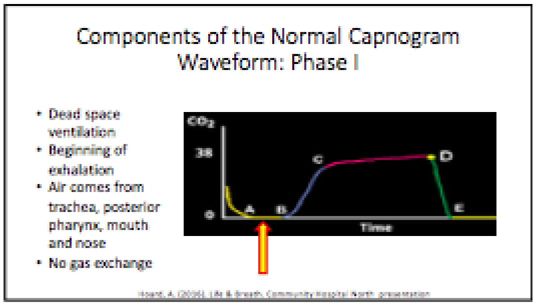

Oxygenation vs. Ventilation
The respiratory cycle is composed of two separate phases:
Oxygenation – The amount of oxygen inhaled by the lungs that reaches the bloodstream. Describes how to get oxygen to the tissues.
Ventilation – Refers to the air movement in and out of the lungs. Describes how to rid of carbon dioxide.

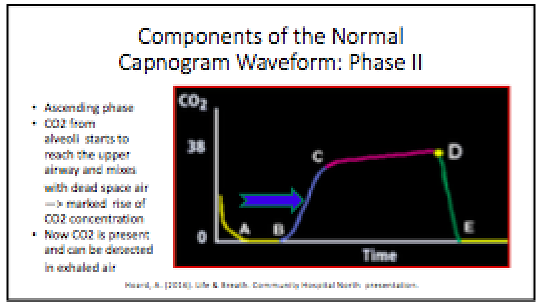

Pulse Oximetry vs. Capnography
Pulse oximetry
Measures oxygen saturation - amount of oxygen carried by hemoglobin
Slow to detect changes in ventilation.
Using supplemental oxygen can mask detection of hypopneic hypoventilation
Hypopneic hypoventilation= decrease tidal volume without change in RR.
Capnography
Provides real time status of ventilation, provides breath to breath ventilation data.
Can detect apneic events immediately

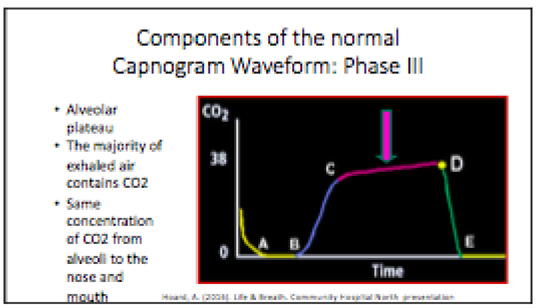

Pulse oximetry present, unlike capnography
79
97
150
82

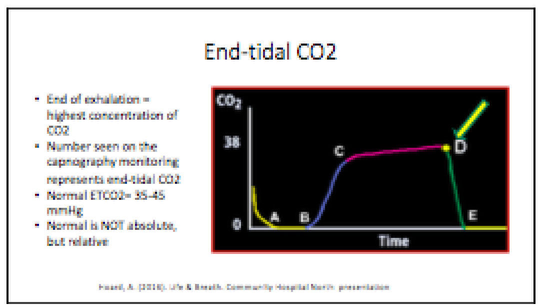

Components of the Normal Capnogram Waveform
CO2
38
0
A
B
C
D
E
Time

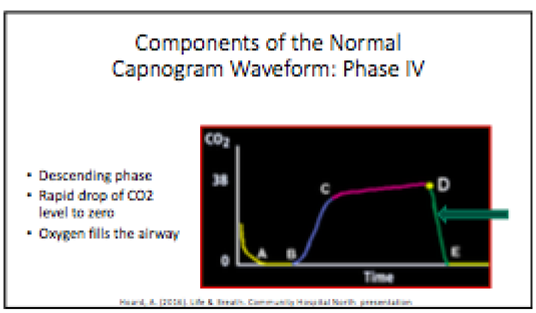
4/17/19

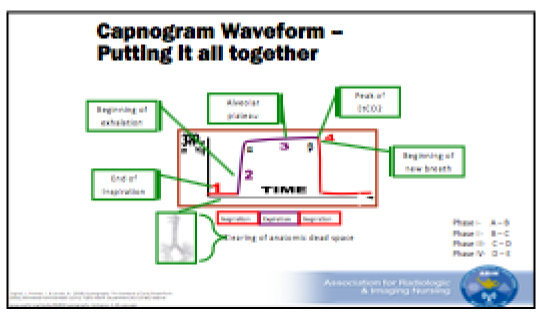

Components of the Normal Capnogram Waveform: Phase I
• Dead space ventilation
• Beginning of exhalation
• Air comes from trachea, posterior pharynx, mouth and nose
• No gas exchange
CO_2
38
0
A
B
C
D
E
Time
Hoard, A. (2016). Life & Breath. Community Hospital North presentation.


Components of the Normal Capnogram Waveform: Phase II
• Ascending phase
• CO2 from alveoli starts to reach the upper airway and mixes with dead space air —> marked rise of CO2 concentration
• Now CO2 is present and can be detected in exhaled air
CO_2
38
0
A
B
C
D
E
Time
Hoard, A. (2016). Life & Breath. Community Hospital North presentation.

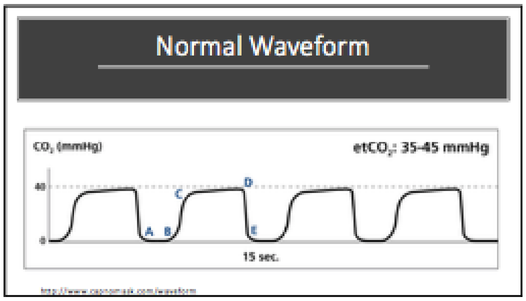

Components of the normal Capnogram Waveform: Phase III
• Alveolar plateau
• The majority of exhaled air contains CO2
• Same concentration of CO2 from alveoli to the nose and mouth
CO_2
38
0
A
B
C
D
E
Time
Hoard, A. (2016). Life & Breath. Community Hospital North presentation.

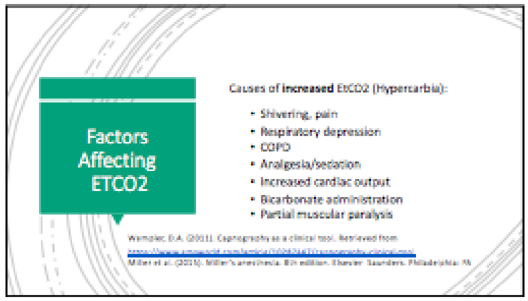

End-tidal CO2
• End of exhalation = highest concentration of CO2
• Number seen on the capnography monitoring represents end-tidal CO2
• Normal ETCO2= 35-45 mmHg
• Normal is NOT absolute, but relative
CO_2
38
0
A
B
C
D
E
Time
Hoard, A. (2016). Life & Breath. Community Hospital North presentation.

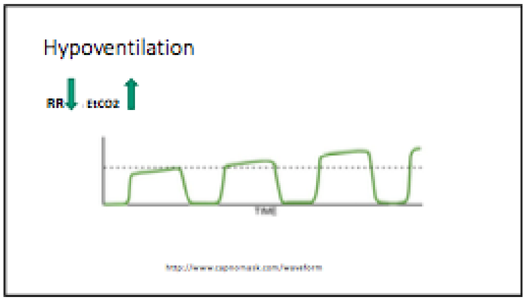

Components of the Normal Capnogram Waveform: Phase IV
• Descending phase
• Rapid drop of CO2 level to zero
• Oxygen fills the airway
CO_2
38
0
A
B
C
D
E
Time
Hoard, A. (2016). Life & Breath. Community Hospital North presentation.

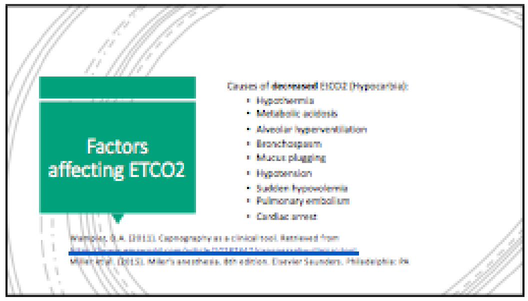

Capnogram Waveform – Putting it all together
Beginning of exhalation
Alveolar plateau
Peak of EtCO2
Beginning of new breath
End of inspiration
1
2
3
4
TIME
Inspiration
Expiration
Inspiration
Clearing of anatomic dead space
Phase I- A – B
Phase II- B – C
Phase III- C – D
Phase IV- D – E
Association for Radiologic & Imaging Nursing

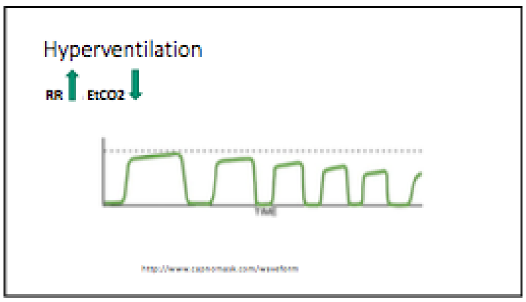
4/17/19

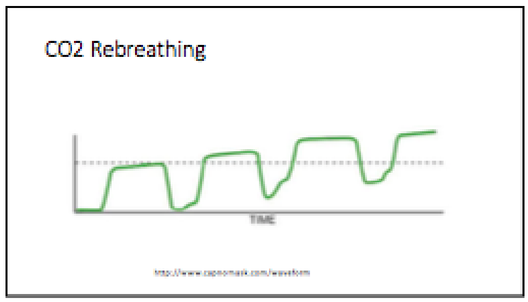

Normal Waveform
CO₂ (mmHg)
etCO₂: 35-45 mmHg
40
0
A
B
C
D
E
15 sec.
http://www.capnomask.com/waveform

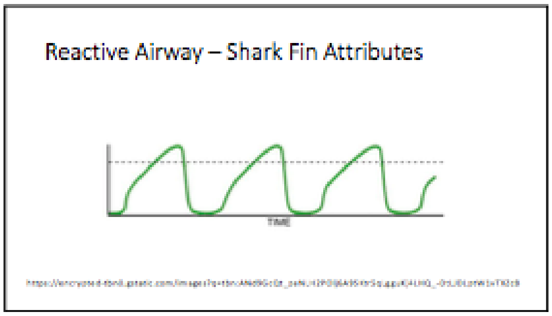

Factors Affecting ETCO2
Causes of increased EtCO2 (Hypercarbia):
• Shivering, pain
• Respiratory depression
• COPD
• Analgesia/sedation
• Increased cardiac output
• Bicarbonate administration
• Partial muscular paralysis
Wampler, D.A. (2011). Capnography as a clinical tool. Retrieved from
Miller et al. (2015). Miller's anesthesia. 8th edition. Elsevier Saunders. Philadelphia: PA

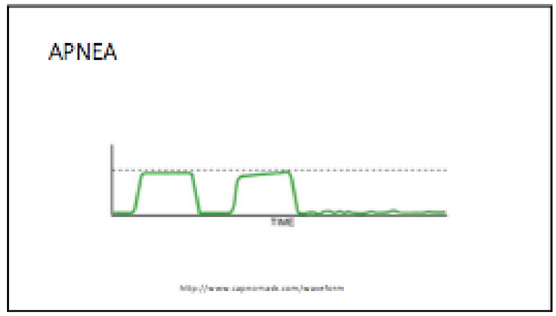

Hypoventilation
RR
EtCO2
TIME
http://www.capnomask.com/waveform

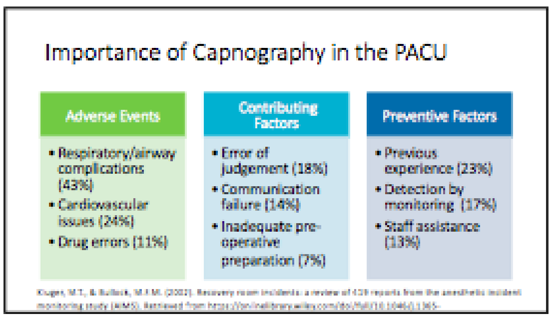

Factors affecting ETCO2
Causes of decreased EtCO2 (Hypocarbia):
• Hypothermia
• Metabolic acidosis
• Alveolar hyperventilation
• Bronchospasm
• Mucus plugging
• Hypotension
• Sudden hypovolemia
• Pulmonary embolism
• Cardiac arrest
Wampler, D.A. (2011). Capnography as a clinical tool. Retrieved from
Miller et al. (2015). Miller's anesthesia. 8th edition. Elsevier Saunders. Philadelphia: PA

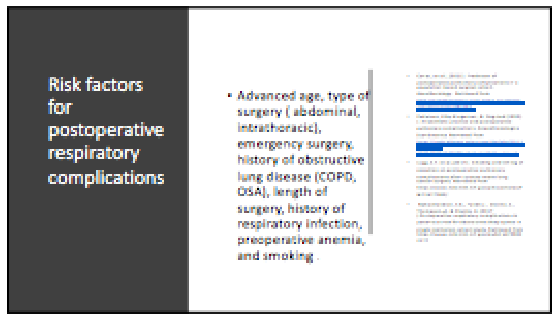

Hyperventilation
RR
EtCO2
TIME
http://www.capnomask.com/waveform

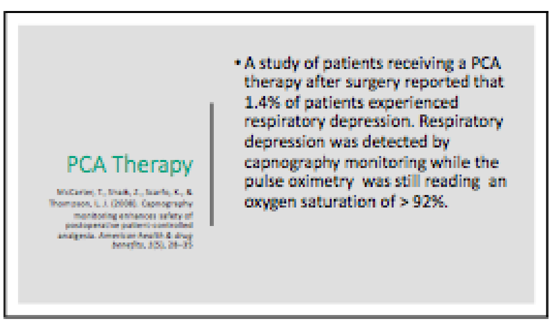

CO2 Rebreathing
TIME
http://www.capnomask.com/waveform

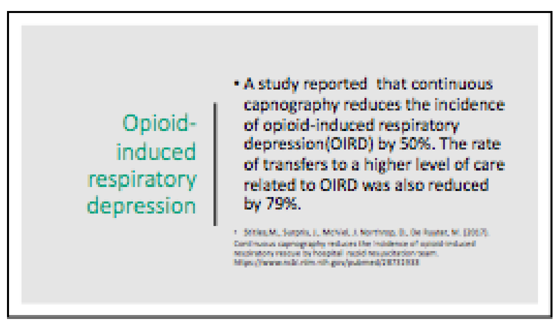

Reactive Airway – Shark Fin Attributes
TIME


APNEA
TIME


Importance of Capnography in the PACU
Adverse Events
• Respiratory/airway complications (43%)
• Cardiovascular issues (24%)
• Drug errors (11%)
Contributing Factors
• Error of judgement (18%)
• Communication failure (14%)
• Inadequate pre-operative preparation (7%)
Preventive Factors
• Previous experience (23%)
• Detection by monitoring (17%)
• Staff assistance (13%)


Risk factors for postoperative respiratory complications
• Advanced age, type of surgery (abdominal, intrathoracic), emergency surgery, history of obstructive lung disease (COPD, OSA), length of surgery, history of respiratory infection, preoperative anemia, and smoking .


PCA Therapy
• A study of patients receiving a PCA therapy after surgery reported that 1.4% of patients experienced respiratory depression. Respiratory depression was detected by capnography monitoring while the pulse oximetry was still reading an oxygen saturation of > 92%.


Opioid-induced respiratory depression
• A study reported that continuous capnography reduces the incidence of opioid-induced respiratory depression(OIRD) by 50%. The rate of transfers to a higher level of care related to OIRD was also reduced by 79%.


?
...
Any
Questions

Appendix F:

Marian University IRB Review Letter

DATE:
TO:
FROM:
RE:
TITLE: SUBMISSION TYPE: ACTION:

DECISION DATE:

Institutional Review Board

January 29, 2019
Bobette Makoyi
Marian University IRB
IRB Protocol # S19.003
Capnography monitoring in the Post Anesthesia Care Unit (PACU) New Project

Determination of Exempt Status

January 28, 2019

The Institutional Review Board at Marian University has reviewed your protocol and has determined the procedures proposed are appropriate for exemption under the federal regulations. However, the Institutional Review Board would like for you to state in your study that nurses will be able to opt out of the research but still receive the in-service training. There will be no further review of your protocol and you are cleared to proceed with your project. The protocol will remain on file with the Marian University IRB as a matter of record.

It is the responsibility of the PI (and, if applicable, the faculty supervisor) to inform the IRB if the procedures presented in this protocol are to be modified or if problems related to human research participants arise in connection with this project. Any procedural modifications must be evaluated by the IRB before being implemented, as some modifications may change the review status of this project. Please contact Karen Spear at (317) 955-6115 or kspear@marian.edu if you are unsure whether your proposed modification requires review. Proposed modifications should be addressed in writing to the IRB. Please reference the above IRB protocol number in any communication to the IRB regarding this project.

Although researchers for exempt studies are not required to complete online CITI training for research involving human subjects, the IRB **recommends** that they do so, particularly as a learning exercise in the case of student researchers. Information on CITI training can be found on the IRB's web-site: http://www.marian.edu/academics/institutional-review-board

Karen L. Spear, Ph.D., Interim-Chair, Marian University Institutional Review Board Cc: Dr. Stacie Hitt.